TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.





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No. 189

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# TORSIONAL STRENGTH OF NICKEL STEEL AND DURALUMIN TUBING AS AFFECTED BY THE RATIO OF DIAMETER TO GAGE THICKNESS.

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# TORSIONAL STRENGTH OF NICKEL STEEL AND DURALUMIN TUBING AS AFFECTED BY THE RATIO OF DIAMETER TO GAGE THICKNESS.*

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## Introduction.

This investigation was made at the request of the Bureau of Aeronautics. Since the ordinary torsion formula is based on elastic resistance to deformation, it is inaccurate for determination of ultimate stresses in thin wall tubing subjected to torsional loads. It has been found that the torsional modulus of rupture varies with the ratio of diameter to gage thickness and the object of these tests was to determine the extent of these variations for subject materials. This is somewhat of a prorogation of work** done by the Army Air Service at McCook Field.

## Conclusions.

1. The torsional modulus of rupture of nickel steel (2330) and duralumin tubing varies with the ratio of diameter to gage thickness (D/t) as follows:

(a) Nickel steel heat-treated for 125,000 Psi ultimate tensile strength.

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* Originally prepared as Report No. 6T23-5, U. S. Naval Aircraft Factory.

** Air Service Information Circular No. 263, Volume III, dated July 20, 1921.

Modulus of rupture (M) = $\frac{135,500}{\sqrt[5]{D/t}}$

(b) Duralumin treated for 55,000 Psi. ultimate tensile strength.

Modulus of rupture (M) $\frac{127,500}{\sqrt{D/t}}$.

Materials.

2. The steel tubing used in this investigation was taken from stock having the following specified analysis:

| Steel No. | % C. | % Mn. | % P. | % S. | % Ni. |
|---|---|---|---|---|---|
| 2330 | .25-.35 | .40-.80 | .40 Max. | .045 Max. | 3.25-3.75 |

The heat treatment given this tubing was that of quenching in oil at 1525° F. and drawing at 800 to 1100° F. depending on the brinell hardness after quenching.

3. The duralumin tubing was standard stock material and since it had been heat-treated by the manufacturer, no further treatment was given. The specified chemical analysis is:

| % Al. | % Cu. | % Mg. | % Mn. | % Fe. | % Si. | % Ca. |
|---|---|---|---|---|---|---|
| 92 Min. | 3.5-5.0 | .2-.75 | .4-1.0 | .6 Max. | .4 Max. | .4 Max. |

## Procedure.

4. Twelve steel and ten duralumin tubes of diameters and gages shown in Table I were supplied in 60-inch lengths. From each of these a 12-inch specimen was cut for tensile tests and the 48-inch lengths used for torsion tests. In the case of steel, the tensile specimens had to be cut before heat treatment due to size of furnace available, which, through heat treatment, resulted in variations in physical properties of the tensile and torsion specimens as will be shown later. The torsion specimens were tested in an Olsen torsion machine at Drexel Institute. The set-up used is shown in photographs (Figures 1 and 2).

## Data.

5. Complete results of these tests are shown in Table I and Figures 8 to 15 inclusive.

6. The curves in Figures 5 and 6 show graphically the changes in moduli of rupture as affected by the D/t ratio. These curves were plotted under the following procedure:

(a) Average curves were drawn through the empirical points for convenience in obtaining the final curves.

(b) Values taken from these average curves were plotted to log scale as shown in Figure 7, from which the slope of the average curves was determined.

(c) Using the slopes thus determined, equations were found from which the final curves shown on Figures 5 and 6 were plotted. These final curves were found to agree very favorably with the original average curves.

7. In Figures 8 to 15 inclusive, the torsional load/deformation data is plotted. Curve G1, (Fig. 13), shows irregularities in the region of the yield point which is characteristic of duralumin.

8. Photographs (Figures 3 and 4) show torsion specimens after test. It will be noted that in all cases but three, failure occurred by buckling or collapsing rather than shear.

## Discussion.

9. In the case of the steel tubing, it will be noted that the empirical values are erratic as shown in Figure 5. This may be due to two causes:

(a) Variations in physical properties of the material.

(b) Failure by crinkling or collapsing rather than shear.

The first cause is not considered entirely responsible as examination of brinell hardness and moduli of rupture of the torsion specimens indicate more uniform physical properties than the tensile values shown in Table I, would suggest. Although the tensile and torsion specimens were heat-treated in

the same furnace and at the same time, their differences in size likely caused considerable variations in physical properties. With due consideration for these erratic results and their causes, the curve is considered sufficiently accurate for reliable design data.

Much credit is due Drexel Institute for courtesies extended in permitting the use of their torsion testing equipment and for generous aid in conducting these tests.

Table I.

STEEL TUBING

Tensile Properties.

| No. | Size | Y.P. Stress | Ult. Stress Psi | % Elong. 2" |
|---|---|---|---|---|
| A1 | 1.000" x .032"Ga. | - | - | - |
| A2 | 1.000 x .032 | - | 129000 | 11.5 |
| B1 | 1.250 x .049 | - | 136800 | 15.0 |
| B2 | 1.250 x .052 | 146800 | 150500 | 12.5 |
| C1 | 1.410 x .065 | 121300 | 124300 | 18.5 |
| C2 | 1.410 x .066 | 109000 | 112200 | 21.0 |
| D1 | 1.500 x .192 | - | - | - |
| D2 | 1.500 x .192 | 140700 | 149200 | 10.0 |
| E1 | 2.250 x .065 | 132200 | 138300 | 10.0 |
| E2 | 2.250 x .065 | 113600 | 128700 | 10.3 |
| F1 | 2.620 x .084 | 108700 | 129600 | 10.8 |
| F2 | 2.620 x .082 | - | - | - |

DURALUMIN TUBING

| No. | Size | Y.P. Stress | Ult. Stress Psi | % Elong. 2" |
|---|---|---|---|---|
| G1 | 0.751 x .057 | 39300 | 66700 | 27.5 |
| G2 | 0.749 x .057 | 38450 | 59700 | 27.5 |
| H1 | 0.998 x .057 | 36800 | 57100 | 17.0 |
| H2 | 0.995 x .057 | 39900 | 61700 | 27.0 |
| I1 | 1.375 x .040 | 31000 | 51100 | 16.0 |
| I2 | 1.370 x .039 | 38900 | 59300 | 20.5 |
| J1 | 1.495 x .042 | 36700 | 58600 | 24.0 |
| J2 | 1.490 x .040 | 37000 | 58200 | 26.0 |
| K1 | 1.500 x .057 | 38500 | 62000 | 25.0 |
| K2 | 1.500 x .059 | 38200 | 61500 | 26.5 |

Notes: 1. J = polar moment of inertia.
2. c = distance from polar axis to extreme fiber or D/2.
3. Load P. limit is torque in inch pounds.
4. Ult. load is torque in inch pounds to rupture.
5. Torsion formula is $S \times J/C = P_p$ where $P_p$ = torque in inch pounds.

Table I (Contd.)

| STEEL TUBING | | | | | |
|---|---|---|---|---|---|
| Torsional Properties. | | | | | |
| No. | Brinall Hardness | D/t | J | C | J/C |
| A1 | 314 | 31.25 | .0228 | 0.500 | .0456 |
| A2 | 239 | 31.25 | .0228 | 0.500 | .0456 |
| B1 | 266 | 25.50 | .0667 | 0.625 | .1067 |
| B2 | 239 | 24.05 | .0703 | 0.625 | .1124 |
| C1 | 248 | 21.70 | .1245 | 0.705 | .1766 |
| C2 | 239 | 21.35 | .1261 | 0.705 | .1788 |
| D1 | 248 | 7.81 | .3445 | 0.750 | .4593 |
| D2 | 236 | 7.81 | .3445 | 0.750 | .4593 |
| E1 | 256 | 34.62 | .5330 | 1.125 | .4737 |
| E2 | 289 | 34.62 | .5330 | 1.125 | .4737 |
| F1 | 222 | 31.20 | 1.0766 | 1.310 | .8218 |
| F2 | 239 | 31.95 | 1.0521 | 1.310 | .8031 |
| | Shore Hardness | DURALUMIN TUBING | | | |
| G1 | 30.0 | 13.17 | .0151 | 0.375 | .0403 |
| G2 | 28.5 | 13.13 | .0149 | 0.374 | .0398 |
| H1 | 27.5 | 17.52 | .0374 | 0.499 | .0749 |
| H2 | 28.5 | 17.46 | .0370 | 0.497 | .0744 |
| I1 | 24.5 | 34.35 | .0748 | 0.687 | .1088 |
| I2 | 24.5 | 35.15 | .0723 | 0.685 | .1055 |
| J1 | 25.5 | 35.60 | .1034 | 0.747 | .1384 |
| J2 | 24.5 | 37.25 | .0957 | 0.745 | .1284 |
| K1 | 25.0 | 26.30 | .1347 | 0.750 | .1786 |
| K2 | 27.0 | 25.45 | .1389 | 0.750 | .1852 |

Table I (Cont.)

| STEEL TUBING | | | | |
|---|---|---|---|---|
| Torsional Properties. | | | | |
| No. | Load at P. Limit | Load at Rupture | Modulus of Rupture P. Lim. | Modulus of Rupture at Ult. |
| A1 | 3125 | 3340 | 68500 | 73200 |
| A2 | 3225 | 3350 | 70750 | 73400 |
| B1 | 7800 | 8200 | 73100 | 77000 |
| B2 | 8150 | 8490 | 73200 | 75500 |
| C1 | 11200 | 11500 | 63400 | 65100 |
| C2 | 11100 | 11700 | 62100 | 65500 |
| D1 | - | 41800 | - | 91000 |
| D2 | 35600 | 42800 | 77500 | 93200 |
| E1 | - | 33700 | - | 71300 |
| E2 | 3360 | 34355 | 71000 | 72500 |
| F1 | 3800 | 49800 | 46200 | 60600 |
| F2 | 5040 | 52400 | 62750 | 65250 |
| DURALUMIN TUBING | | | | |
| G1 | 880 | 1615 | 21800 | 40100 |
| G2 | 855 | 1220 | 21500 | 30600 |
| H1 | 1400 | 2310 | 18700 | 30850 |
| H2 | 1450 | 2455 | 19500 | 33000 |
| I1 | 1700 | 2375 | 15600 | 21800 |
| I2 | 1690 | 2420 | 16000 | 22900 |
| J1 | 2500 | 3000 | 18050 | 21550 |
| J2 | 2500 | 2950 | 19450 | 22950 |
| K1 | 3250 | 4600 | 18200 | 25750 |
| K2 | 3200 | 4550 | 17250 | 24550 |

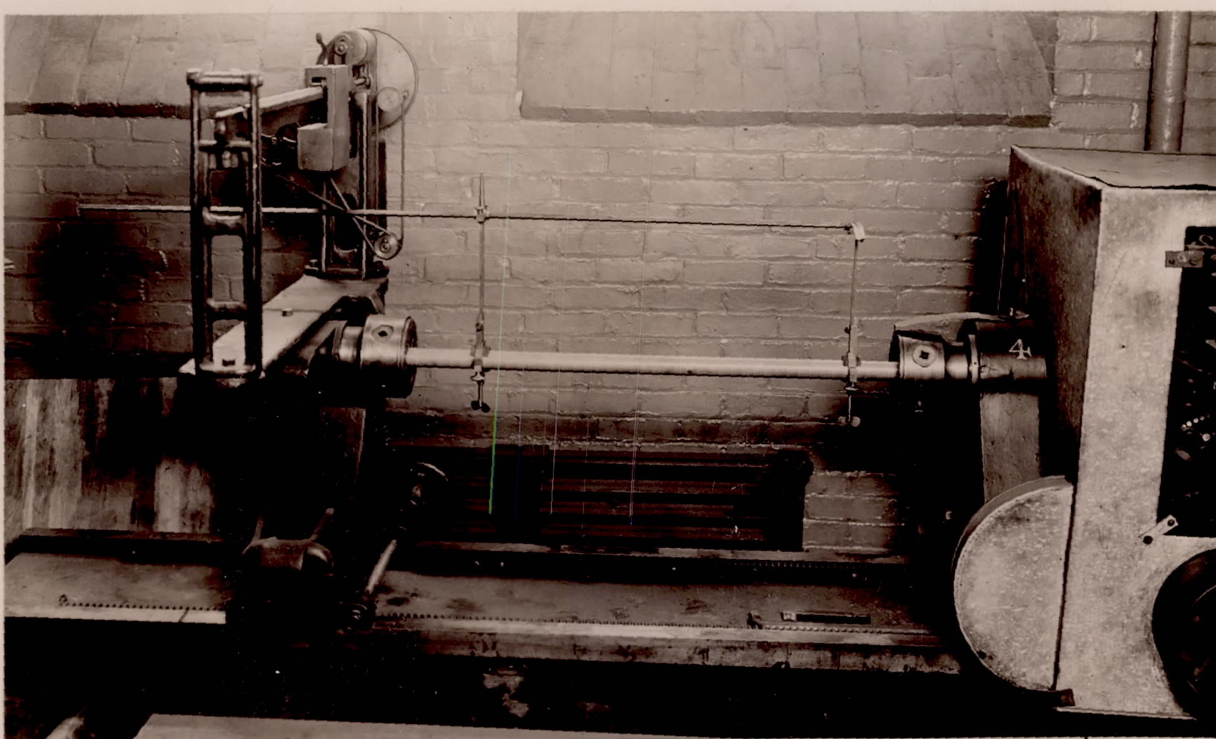

Fig.1.

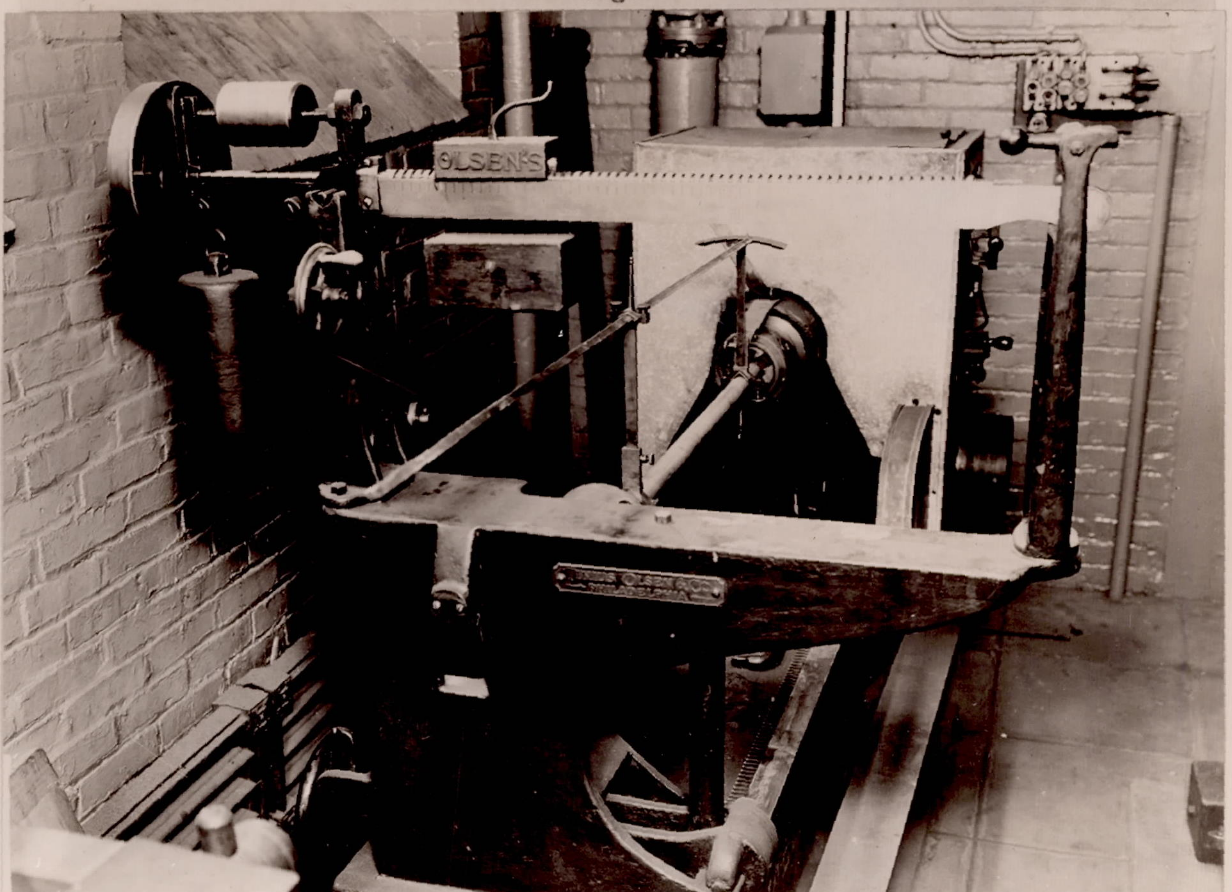


Fig.2. Set-up for test at Drexel Institute.

N.A.C.A.
11425 A.S.

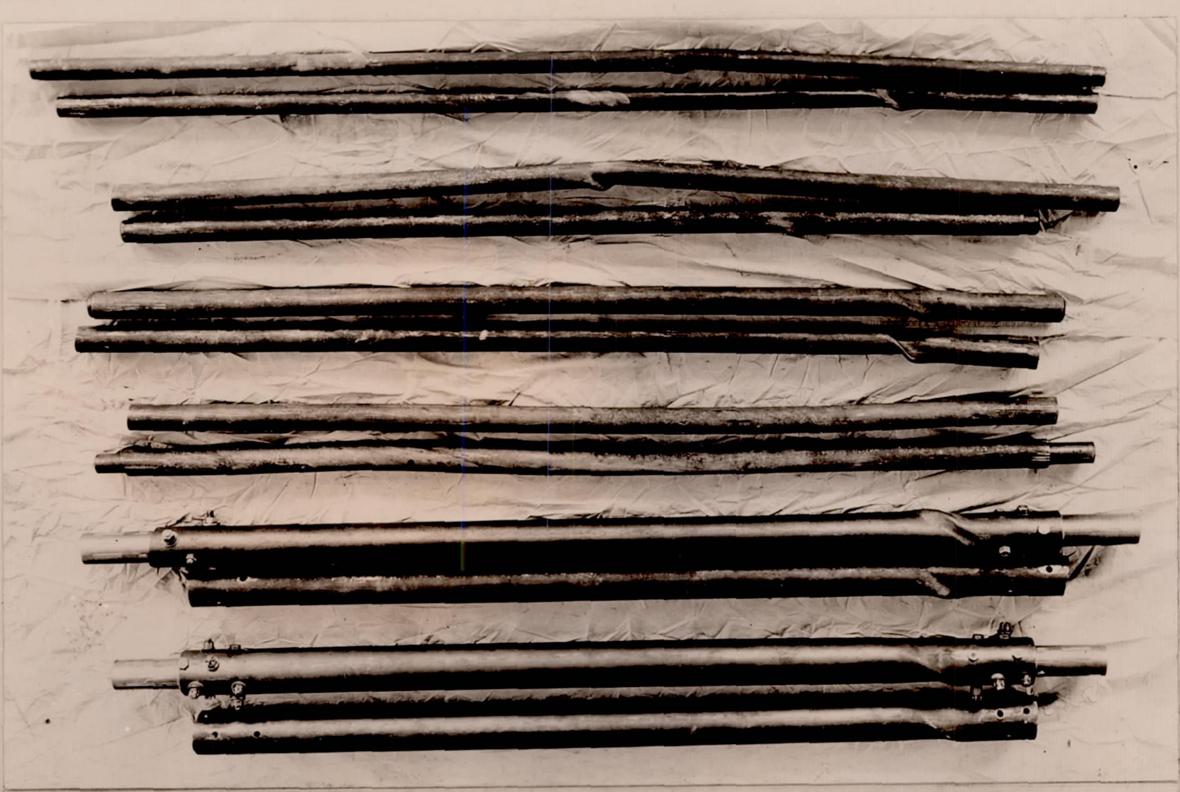

Fig.3. Torsion test on 2330 steel tubing.

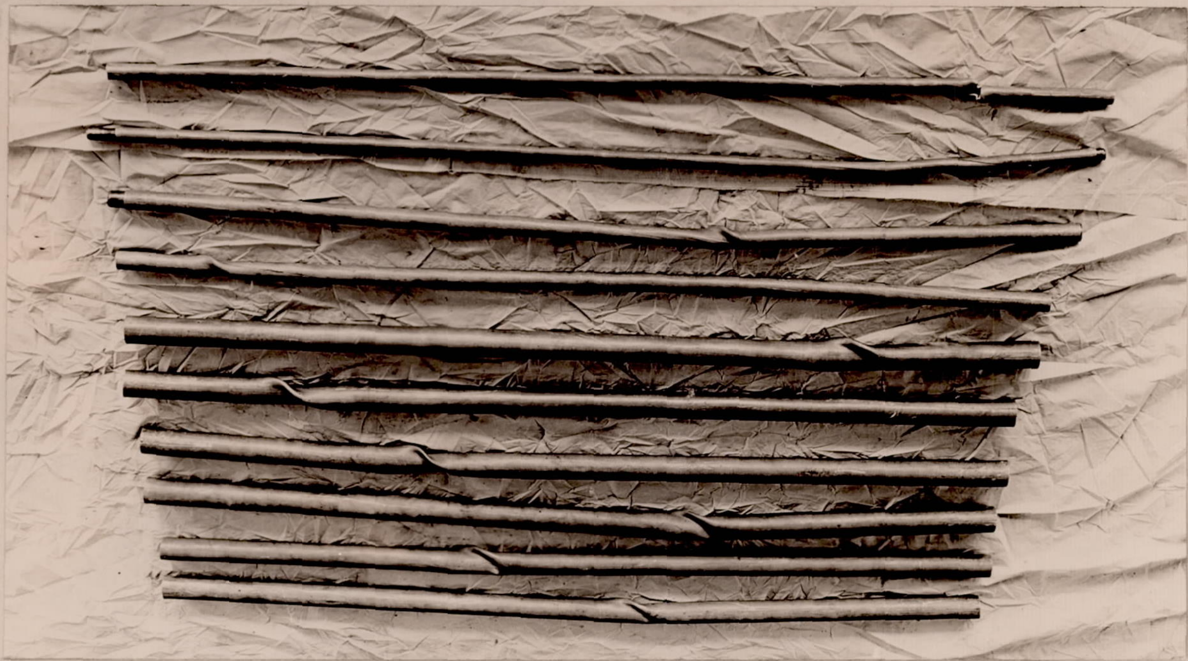

Fig.4. Torsion test on duralumin tubing.

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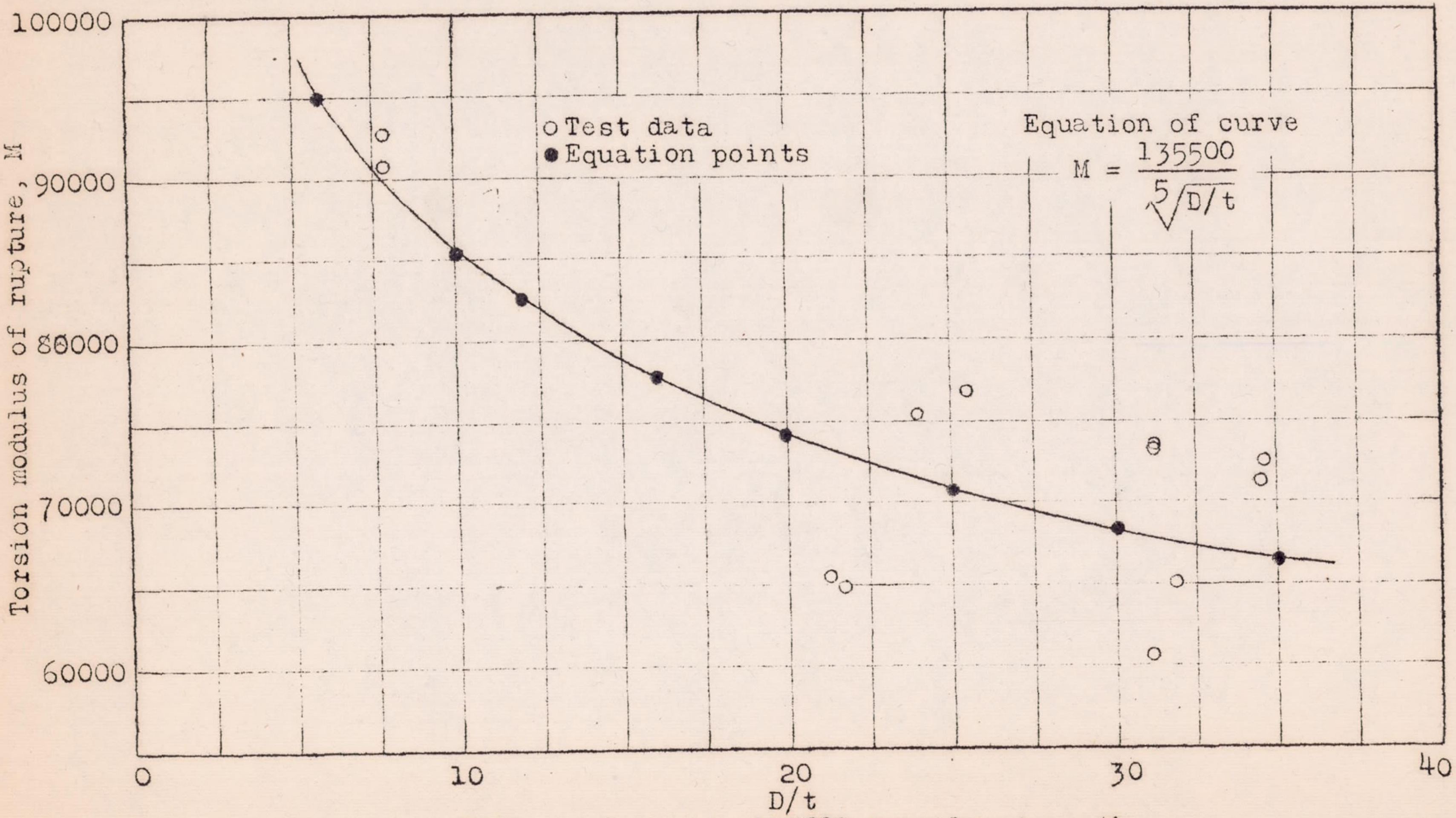



Fig. 5 2330 steel tubing 125000 tensile strength

Fig. 5

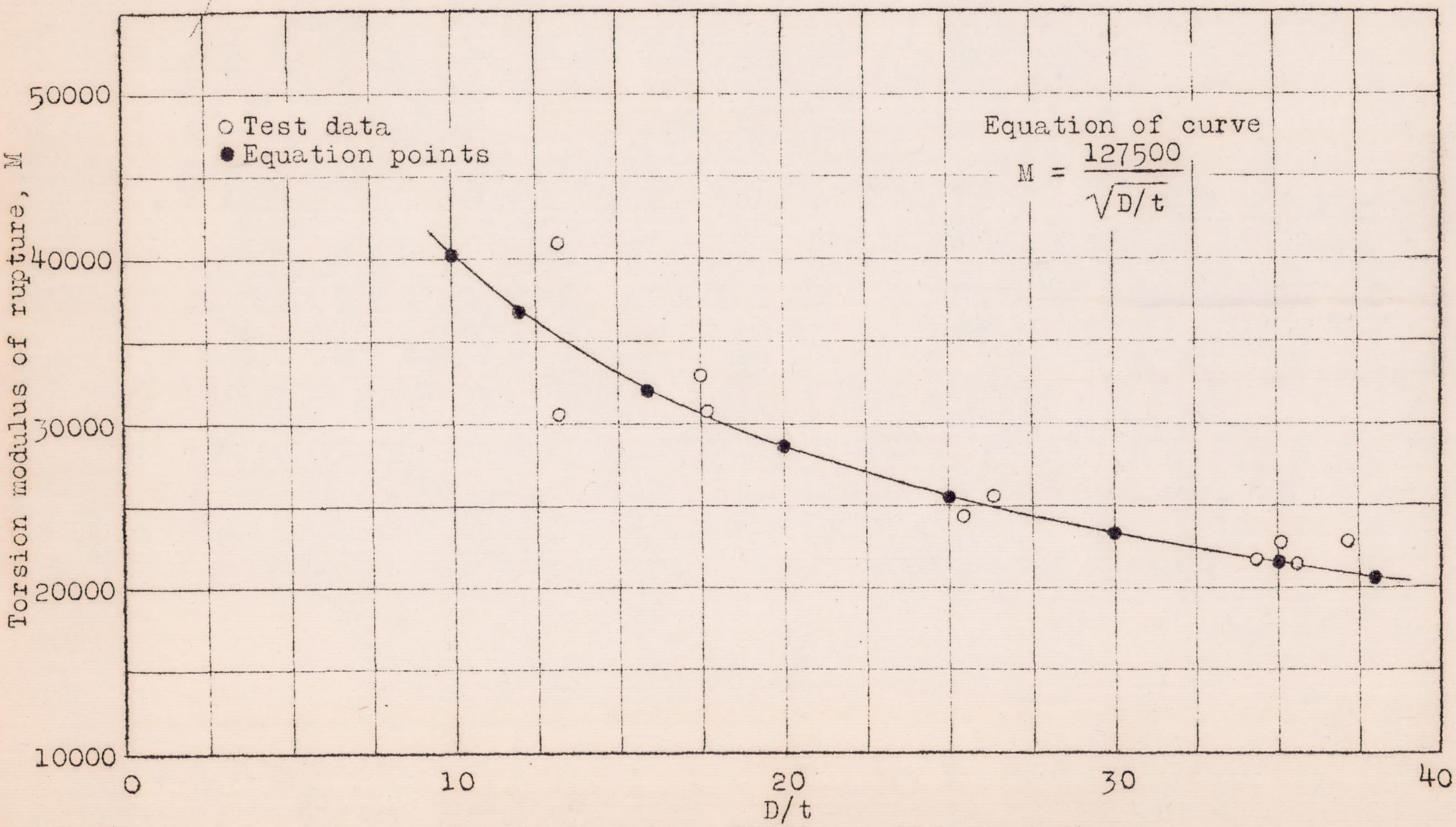
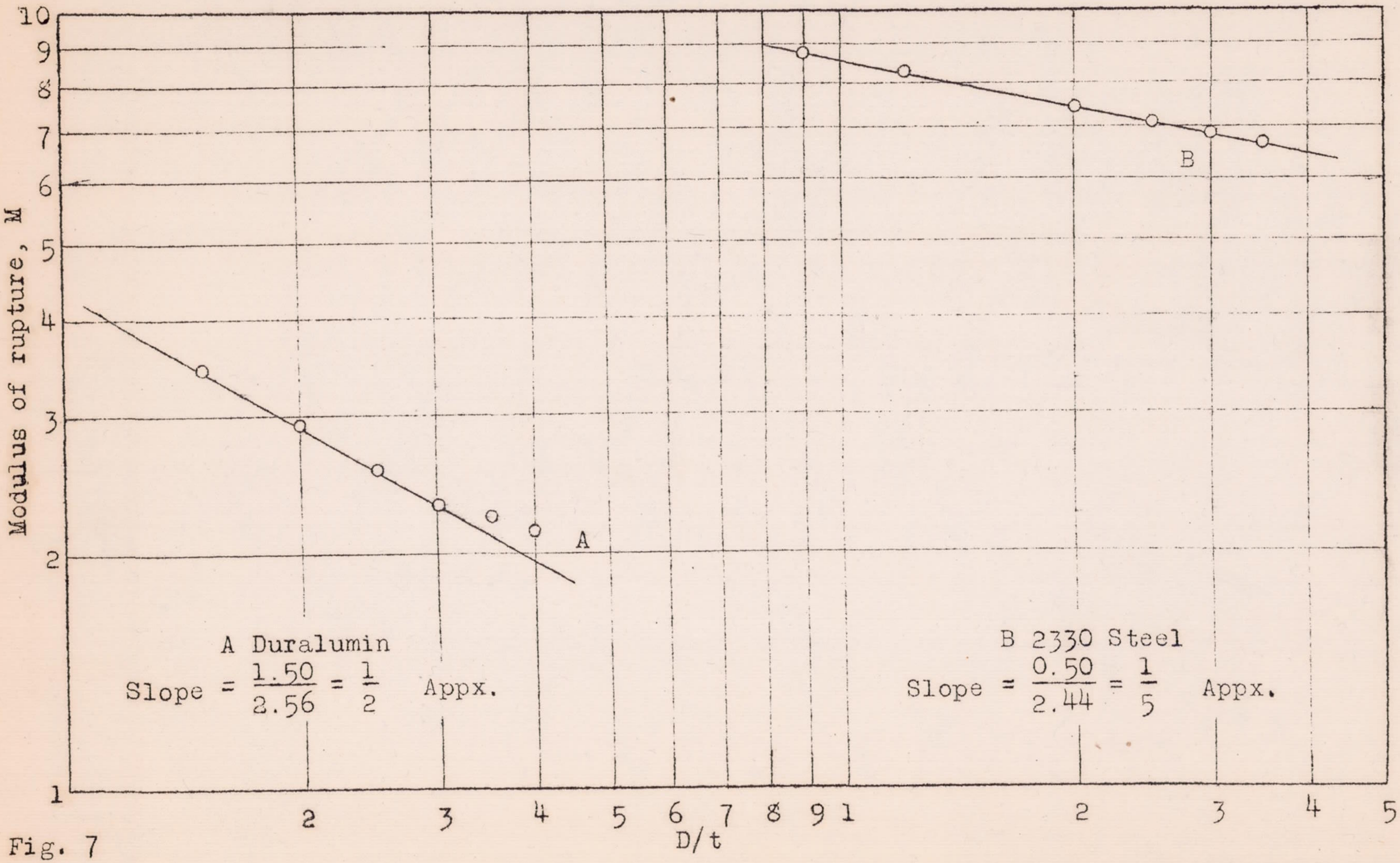



Fig. 6

Duralumin tubing 55000 tensile strength

Fig. 6



10
9
8
7
6
5
4
3
2
1
Modulus of rupture, M
A
B
A Duralumin
Slope = $\frac{1.50}{2.56} = \frac{1}{2}$ Appx.
B 2330 Steel
Slope = $\frac{0.50}{2.44} = \frac{1}{5}$ Appx.
2
3
4
5
6
7
8
9
1
2
3
4
5
D/t


Fig. 7

Fig. 7

Fig. 8

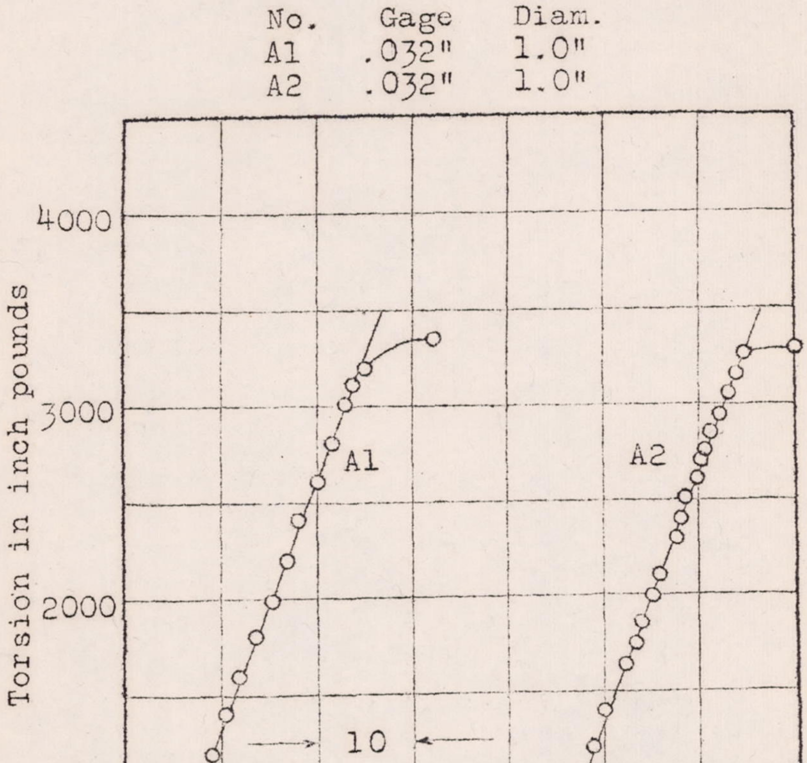



Fig. 8 Alloy steel tubing

Fig. 9

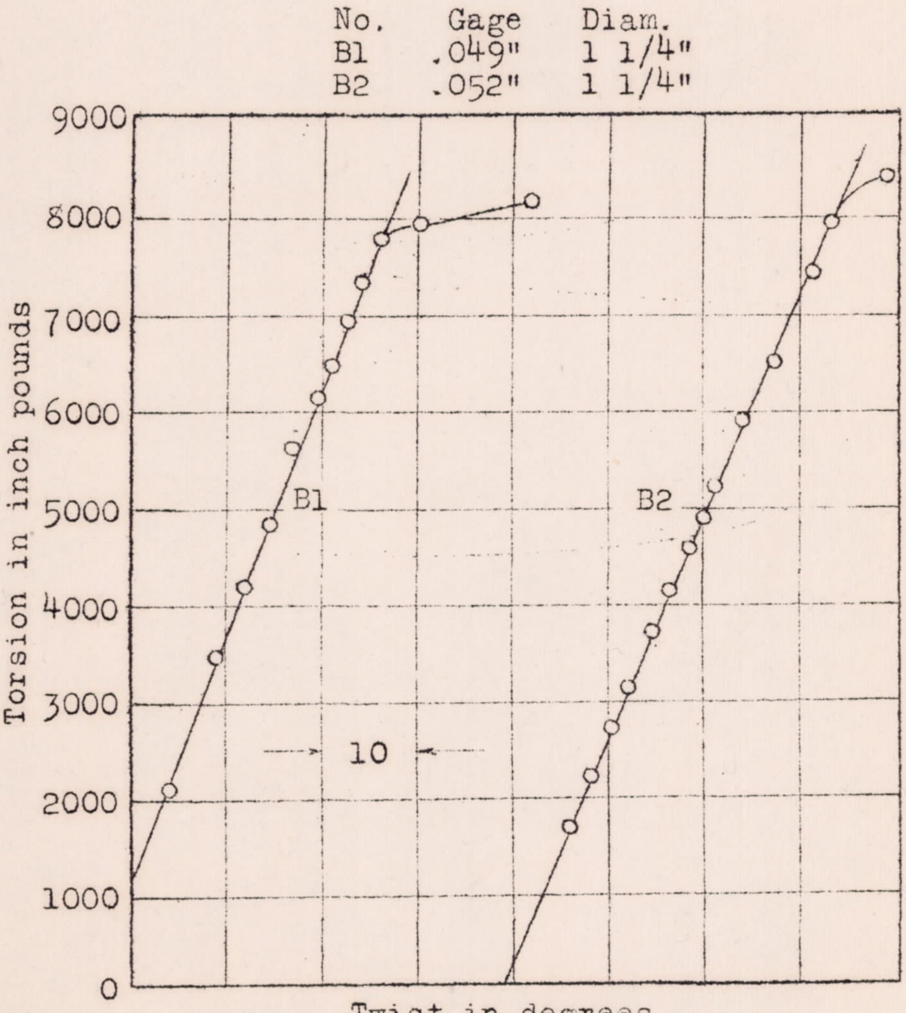



Fig. 9 Alloy steel tubing

Fig. 10

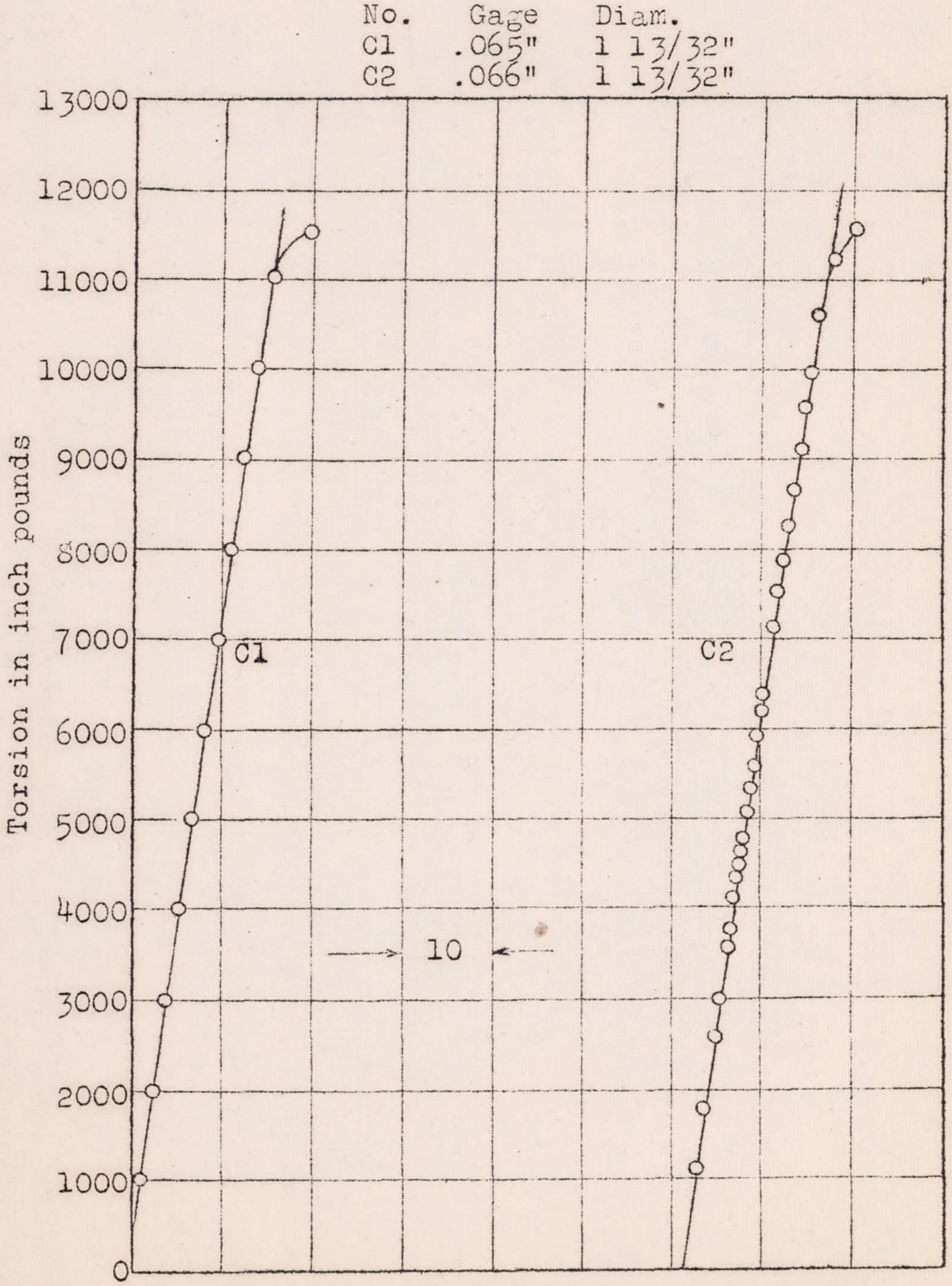



Fig. 10 Alloy steel tubing

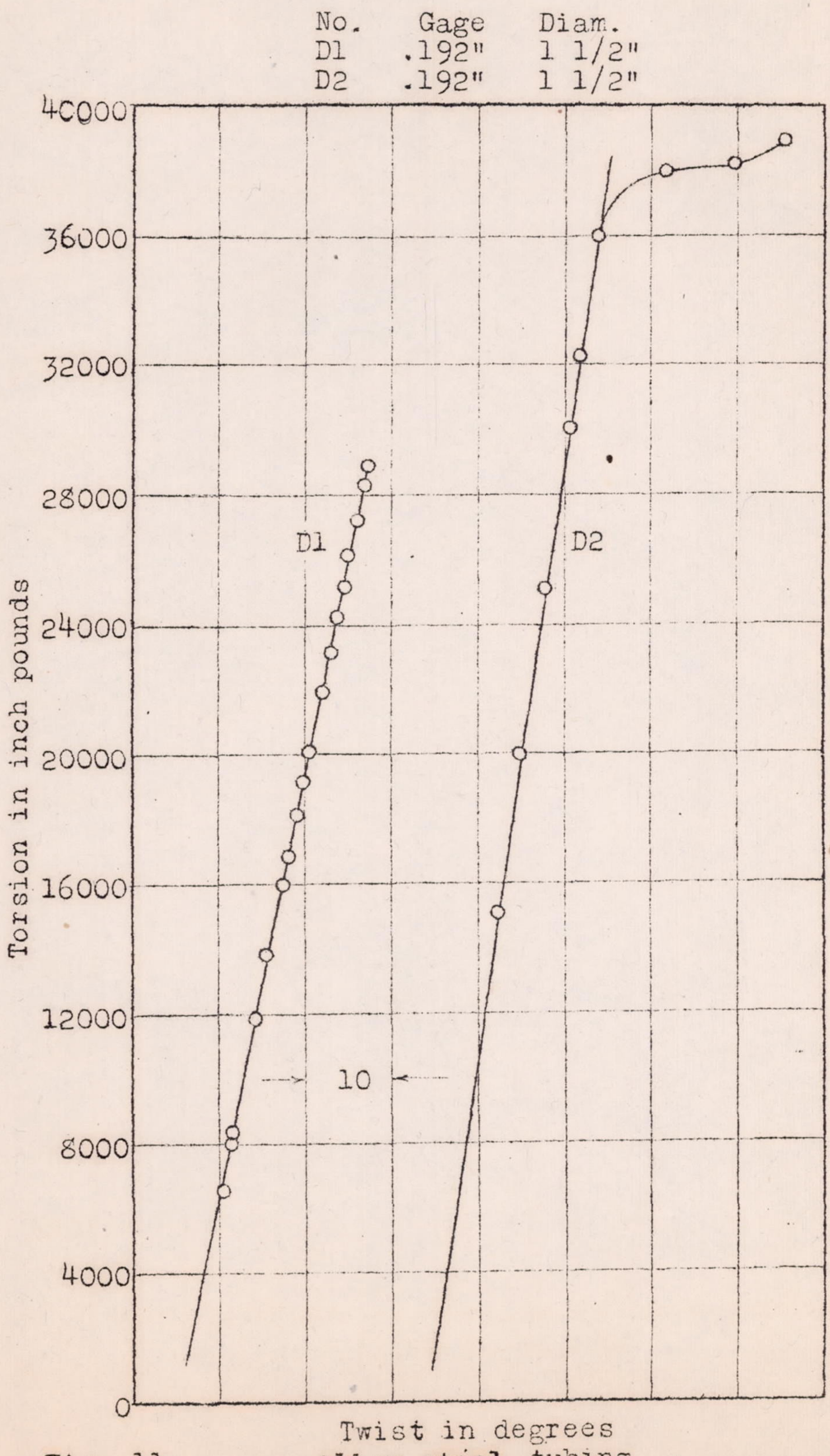
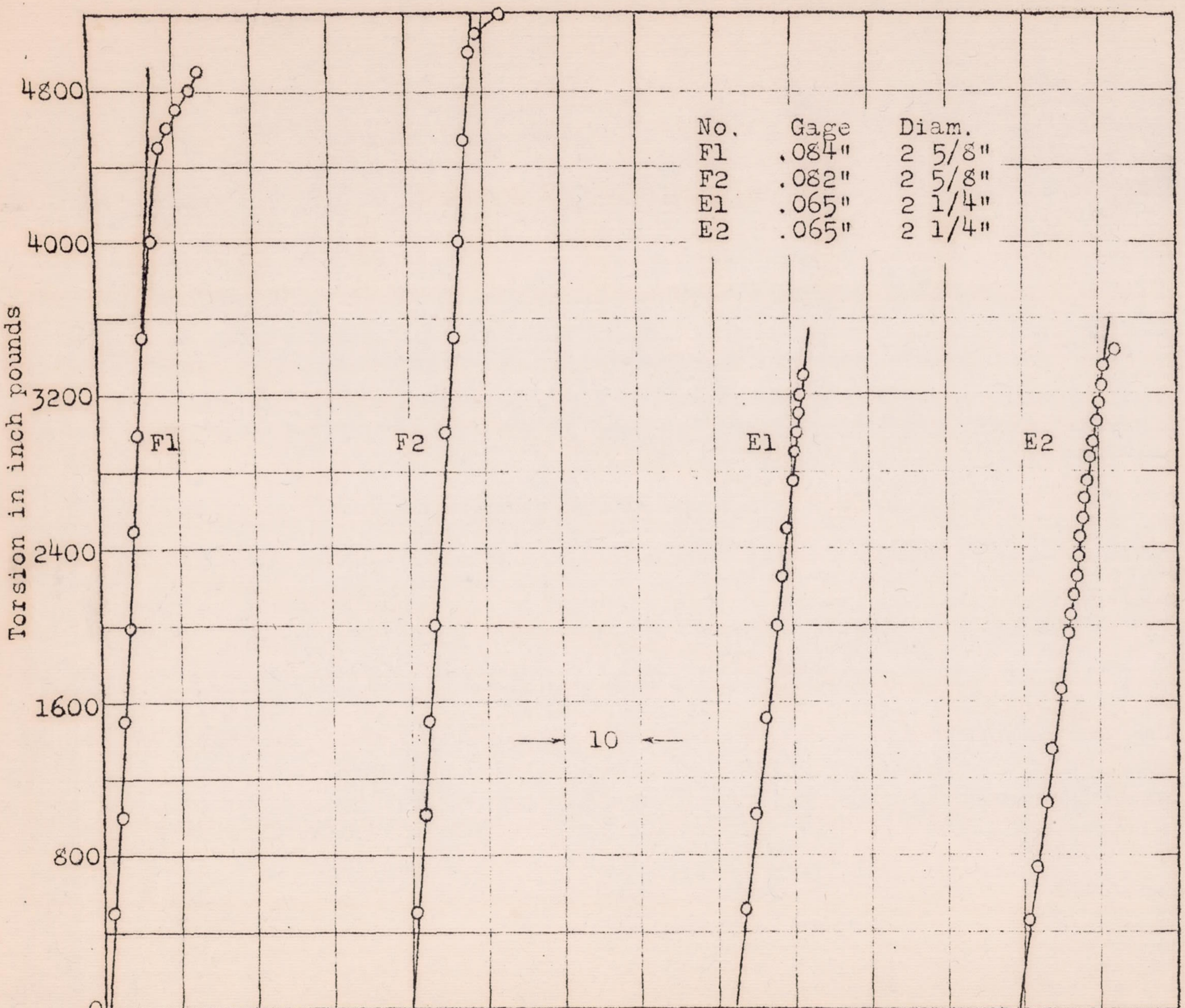



Fig. 11 Alloy steel tubing



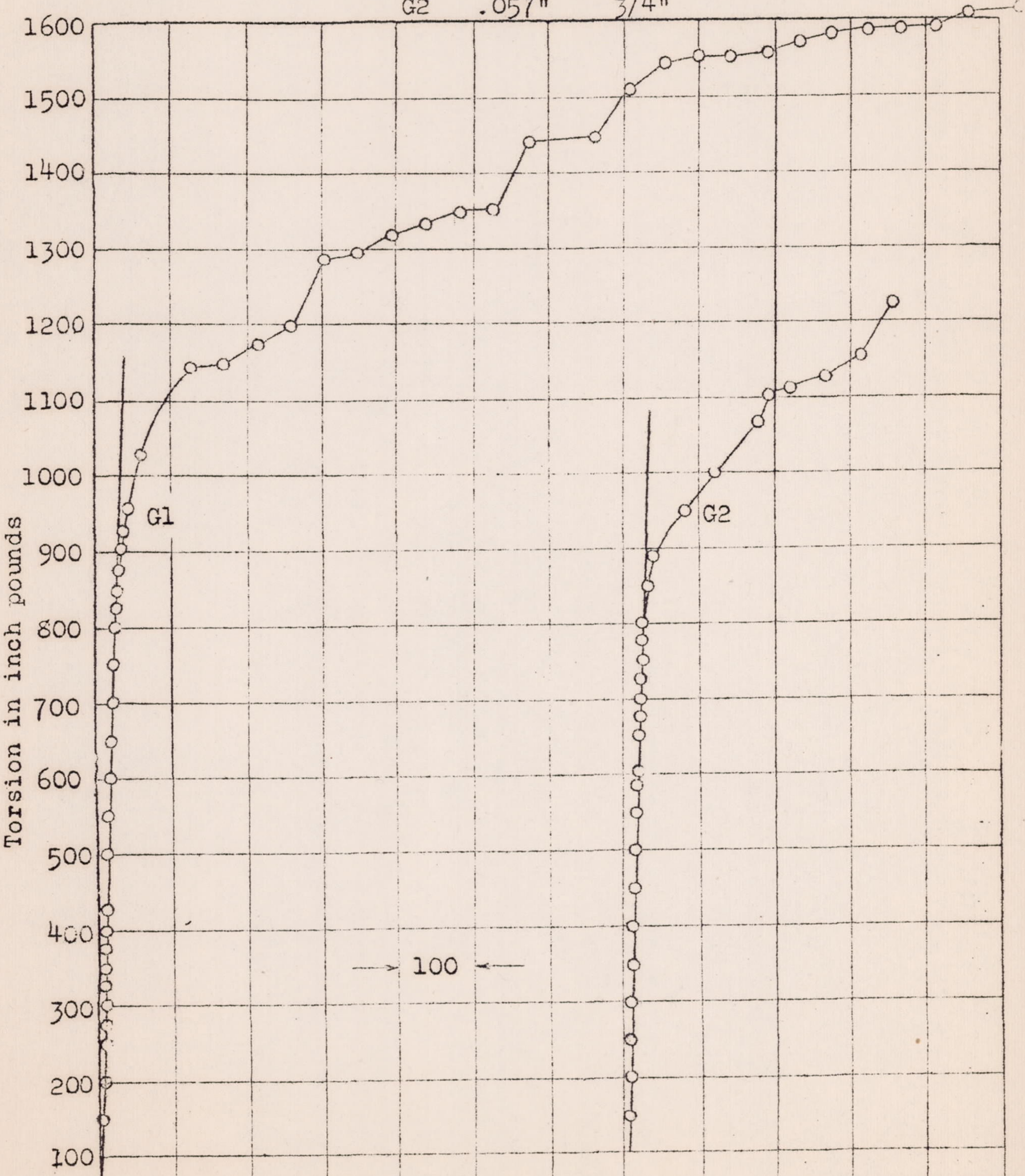

Twist in degrees
Alloy steel tubing

Fig. 12

Fig. 12

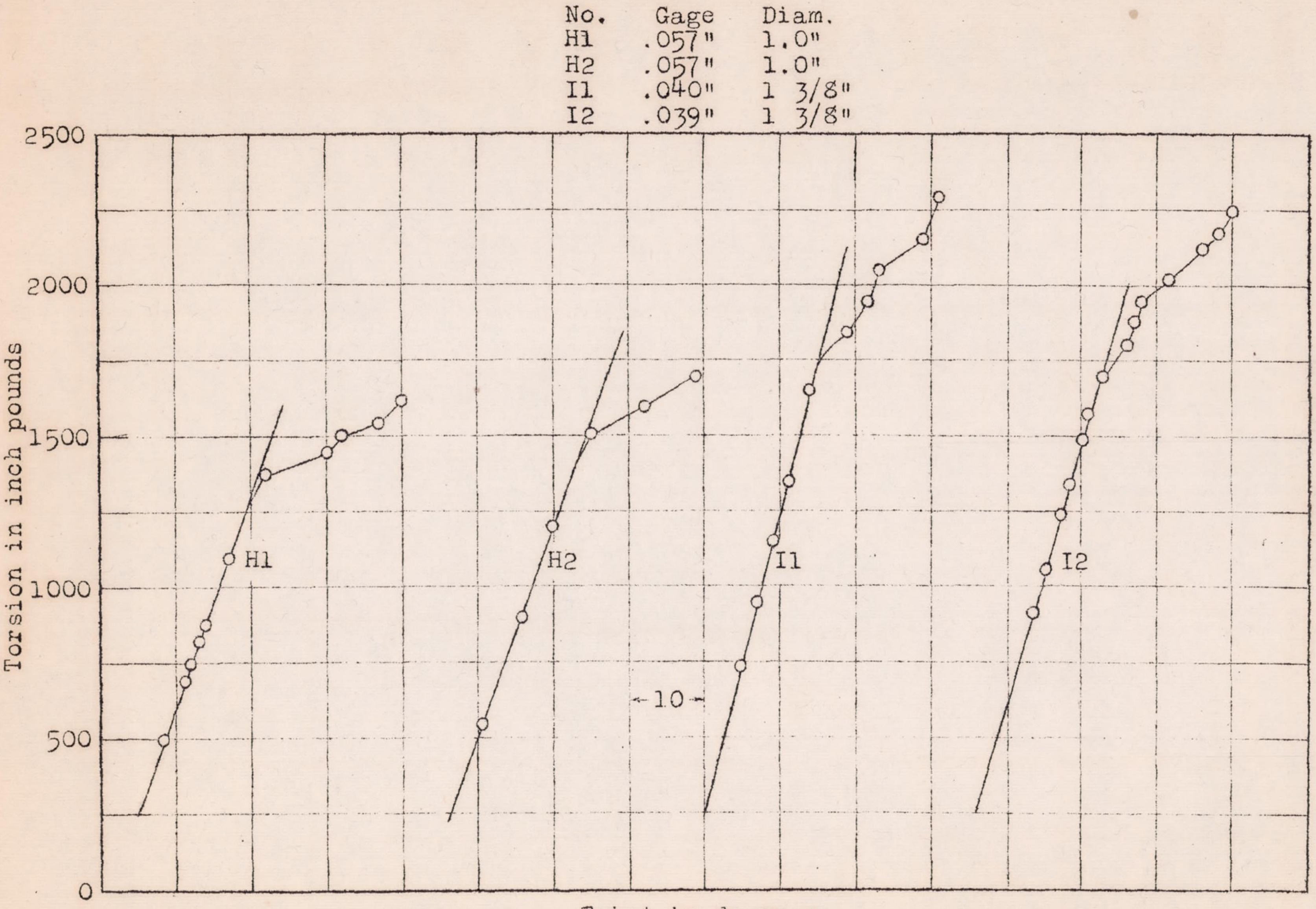
Fig. 13

| No. | Gage | Diam. |
|---|---|---|
| G1 | .057" | 3/4" |
| G2 | .057" | 3/4" |




Twist in degrees
Duralumin tubing

Fig. 13




Twist in degrees
Duralumin tubing

Fig. 14

Fig. 14

| No. | Gage | Diam. |
| --- | --- | --- |
| J1 | .042" | 1 1/2" |
| J2 | .040" | 1 1/2" |
| K1 | .057" | 1 1/2" |
| K2 | .059" | 1 1/2" |

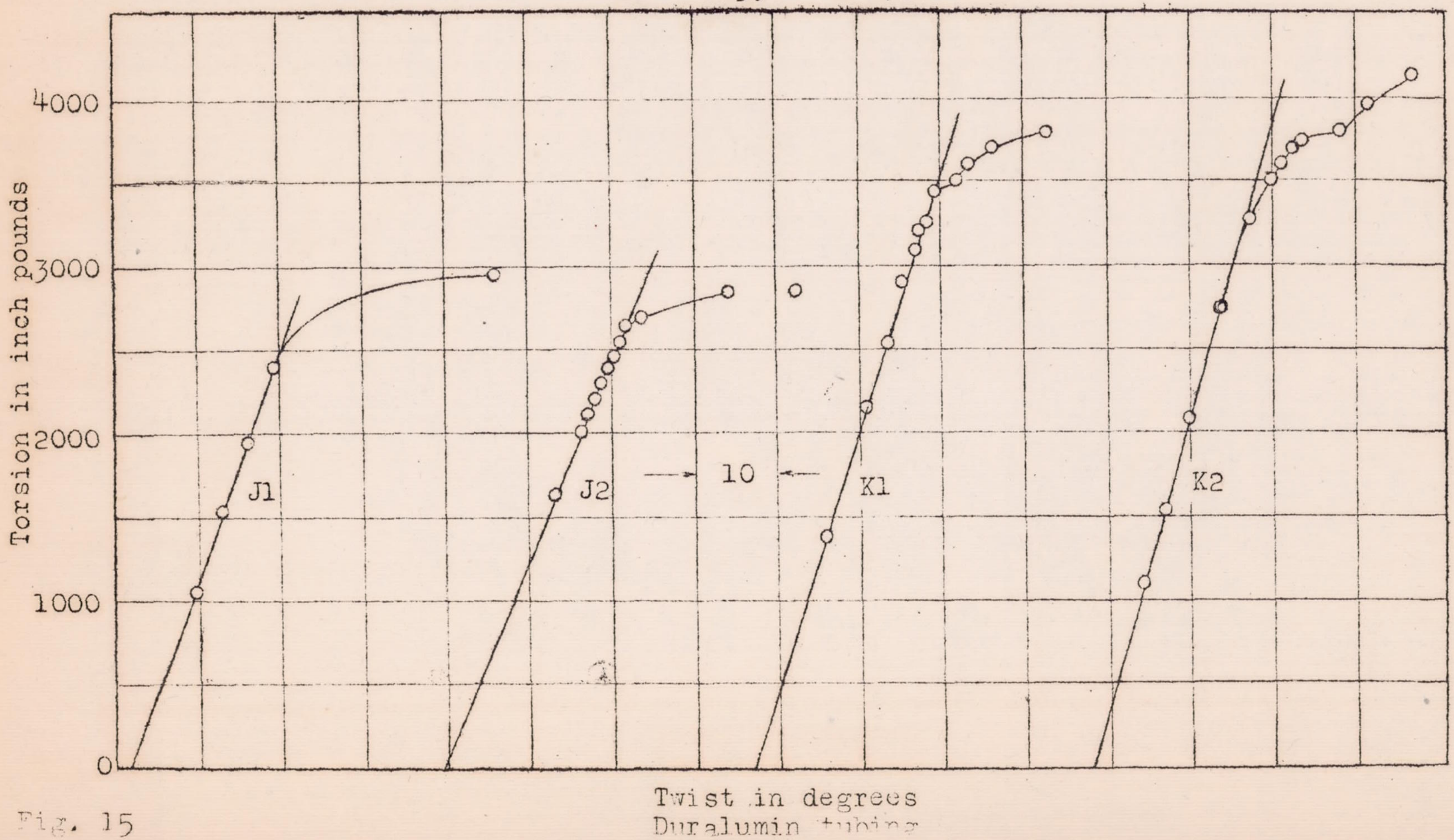



Fig. 15

Fig. 15